Updating the Sandia islanding guidelines document

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Topics in this presentation

- Discussion of the "Type System" as a new screening basis
- Learning from recent Sandia-sponsored work on risk posed by cases not covered by IEEE 1547.1 testing
- Learning from recent EPRI-sponsored study on the sensitivity of ROTs to various factors

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Necessary condition for sustained islanding

- **Real and reactive sources and sinks are such that one can obtain a balance within the prospective island.**
- In general, if there is a P imbalance:
  - For GLR < 1, V falls.
  - For GLR > 1, V rises.
- In general, if there is a Q imbalance:
  - For a net-inductive island, f rises.
  - For a net-capacitive island, f falls.

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Situations NOT tested by UL-1741 or IEEE 1547.1

- Multiple inverters
- Mixtures of dissimilar inverters
- Mixtures of inverters and rotating machines
- Other than const-Z loads
- **Why not?**
  - **Where does the test matrix stop?**
  - **Logistical difficulties.**

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Why islanding is reemerging as a concern

- Much higher DG deployment levels means more of the problem cases.
- Have seen some power quality issues caused by anti-islanding. (Also stability issues in weak grids.)
- Grid support function impacts have raised concerns.
    - RTs
    - V/V, f/W, etc.
- MANY new market entrants, with a wide array of different techniques; some are proven, some are not.

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Origins of the real power screen

$$Z_{load} = \frac{V_{nom}^2}{P_{load}} \rightarrow V_{nom}^2 = P_{load} Z_{load}$$

$$V_{isl}^2 = P_{DER} Z_{load}$$

$$\frac{V_{isl}}{V_{nom}} = \sqrt{\frac{P_{DER}}{P_{load}}} \leq 0.88$$

$$\downarrow$$

$$\frac{P_{DER}}{P_{load}} \leq (0.88)^2 = 0.77$$

From here, 0.67 (2/3) was chosen for margin and simplicity.

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Real power screen details

- Assumptions:
  - The inverter acts as a constant-power current source (acceptable assumption after the first few cycles of an island).
  - The 2-s undervoltage trip is at 0.88 pu. (No longer true in the new version of 1547.)

$$\frac{V_{isl}}{V_{nom}} = \sqrt{\frac{P_{DER}}{P_{load}}} \leq 0.5$$

$$\frac{P_{DER}}{P_{load}} \leq (0.5)^2 = 0.25$$

You can all imagine how popular THIS would be.

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Origins of the var screen

- It is possible to derive the following relationship between the island frequency, the EPS frequency, and the var balance in the island*:

$$f_{isl} = f_{EPS}\sqrt{\frac{(Q_L + Q_{LG})}{(Q_C + Q_{CG})}} \rightarrow \frac{Q_{L,isl}}{Q_{C.isl}} = \left(\frac{f_{isl}}{f_{EPS}}\right)^2$$

- For the 60.5 Hz OF trip, the squared quantity = 1.0167. From there, the 1% var match criterion was selected for simplicity and margin.

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*G. Kern, M. Ropp, S. Gonzalez, "Power Balance Requirements for Sustained Islanding of Inverter Based Distributed Generation", proceedings of the 44th IEEE Photovoltaics Specialists Conference, July 2017.

Var screen details

- Assumptions:
  - The load Q doesn't change appreciably when the island forms.
  - The inverter vars do not change appreciably during islanding.
  - The closest frequency trip is at 60.5 Hz.

$$\frac{Q_{L,isl}}{Q_{C.isl}} = \left(\frac{f_{isl}}{f_{EPS}}\right)^2 = \left(\frac{62}{60}\right)^2 = 1.068$$

So we would now have a ~7% (or more) var matching criterion. This would catch nearly all PV installations.

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Working toward the new Sandia screens

- Now completing a new set of Sandia-sponsored work intended to move toward a new version of the Sandia screens. Features:
  - Dispense with the P and Q screens altogether; focus instead on the cases NOT covered by 1547.1 type testing.
  - Simplify data gathering by establishing inverter AI types and quantifying relationships between these.
- Some progress, but some challenges…

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New Sandia screens: islanding detection types (W.I.P.)

- **AI Type 1:** fundamental-freq pos-seq perturbation that grows continuously in magnitude as frequency error increases, with no dead zone. ("Pure" SFS and quasi-SFS.)
- **AI Type 2A:** Type 1 but not continuous to the trip limits, except *not* a dead zone.
- **AI Type 2B:** Type 2A, with a dead zone.
- **AI Type 3:** pos-seq perturbation without feedback (Z detection).
- **AI Type 4:** harmonic injection specifically for AI.
- **AI Type 5:** passive AI only.
- **AI Type 6:** negative sequence manipulation.

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Challenges

- No more than ten types, but still comprehensive coverage
- Type definitions must be EXTREMELY clear and unambiguous
  - Manufacturers must be able to tell easily which type they are
  - No inverter should fall into more than one type

Vs	Amount of Class 1 DG						
	0%	10%	25%	50%	75%	90%	100%
2A	0	0	0	0	0	0	0
2B	1.18	0.12	0	0	0	0	0
3	2.47	0.35	0	0	0	0	0
5	2.35	0.35	0	0	0	0	0
6	0	0	0	0	0	0	0

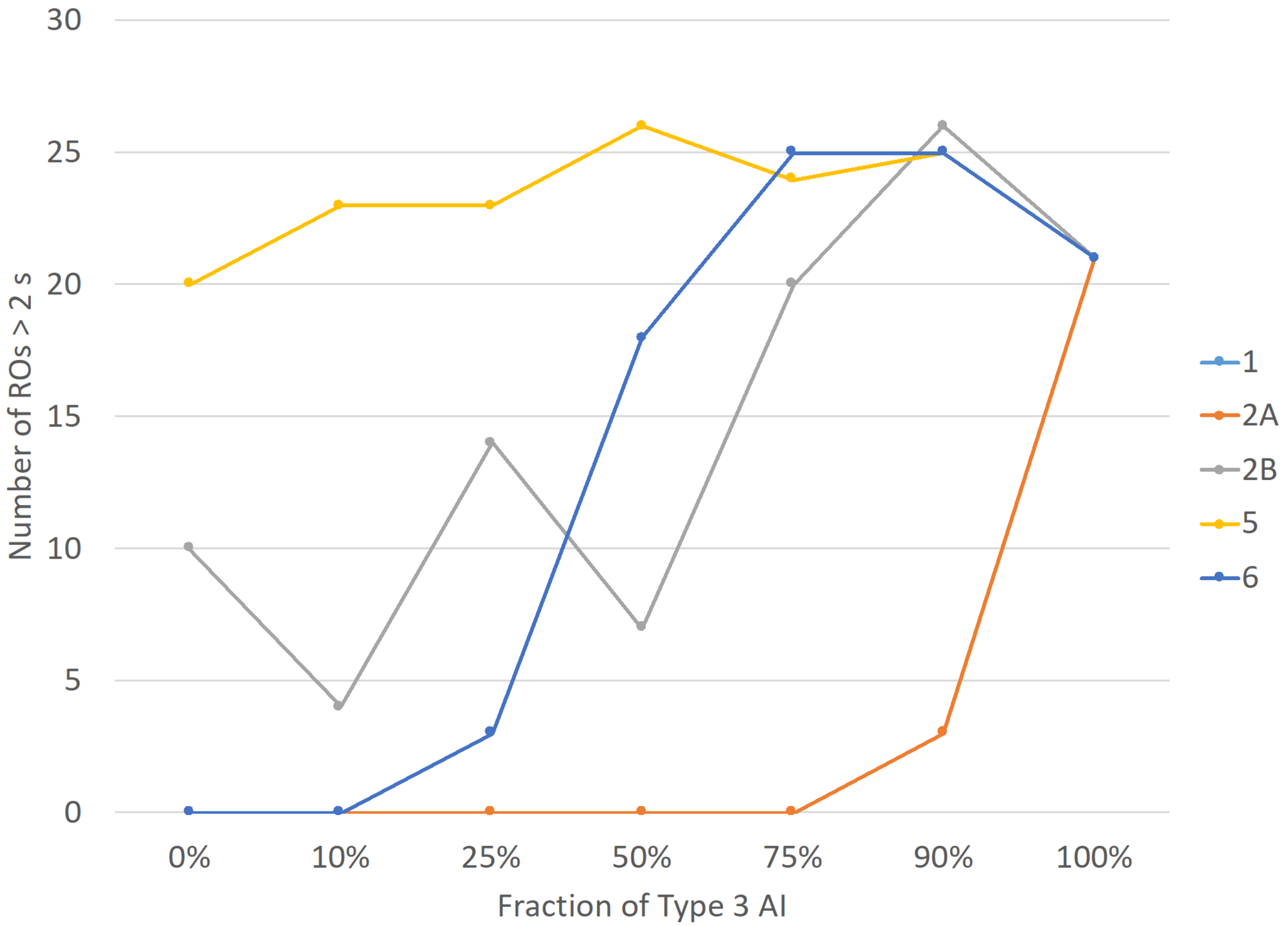
Vs	Amount of Class 3 DG						
	0%	10%	25%	50%	75%	90%	100%
1	0	0	0	0	0	0.35	2.47
2A	0	0	0	0	0	0.35	2.47
2B	1.18	0.47	1.65	0.82	2.35	3.06	2.47
5	2.35	2.71	2.71	3.06	2.82	2.94	2.47
6	0	0	3	18	25	25	21

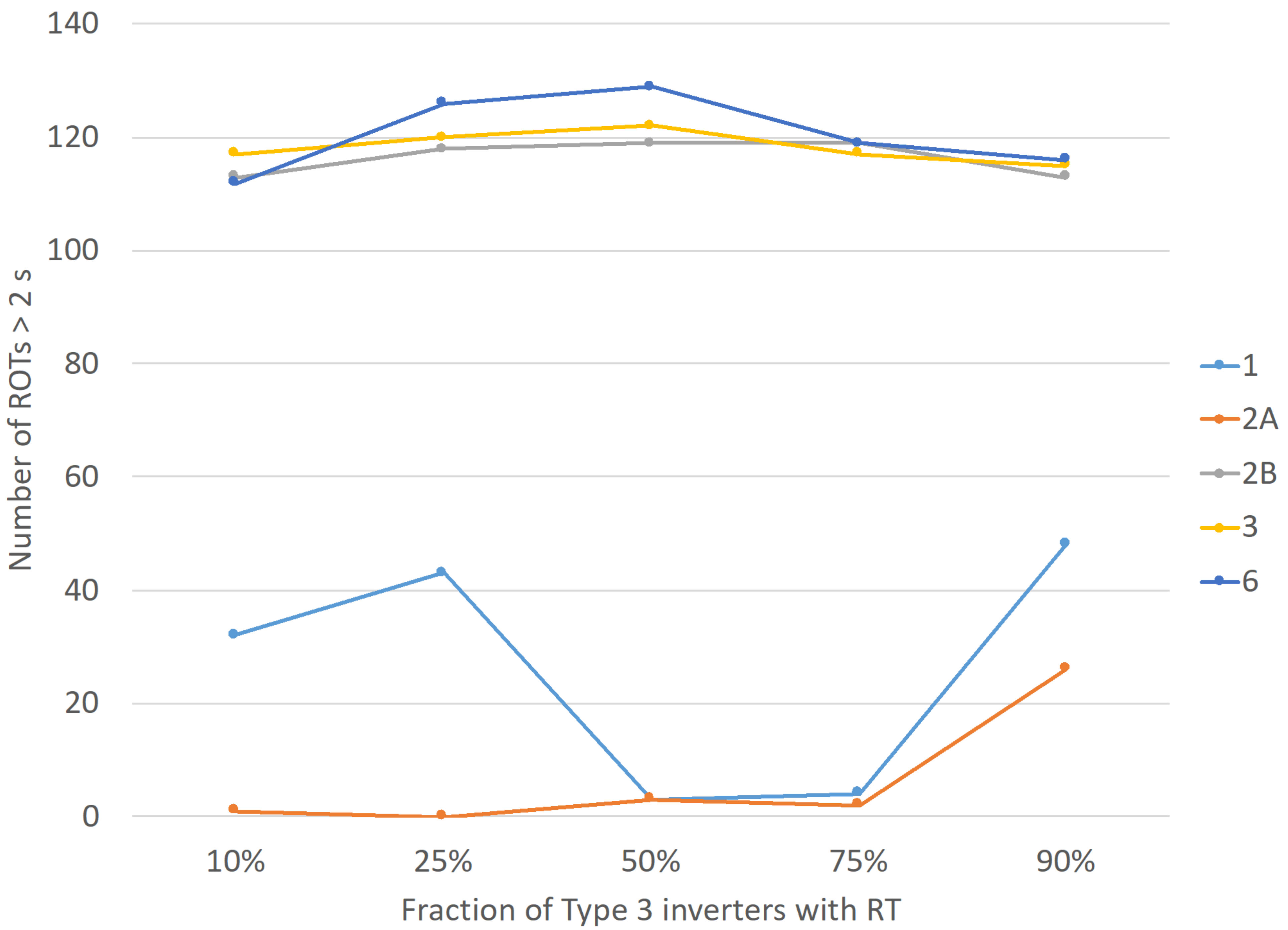
Vs	Amount of Class 2A DG						
	0%	10%	25%	50%	75%	90%	100%
1	0	0	0	0	0	0	0
2B	1.18	0	0	0	0	0	0
3	2.47	0.35	0	0	0	0	0
5	2.35	0.35	0	0	0	0	0
6	0	0	0	0	0	0	0

Vs	Amount of Class 5 DG						
	0%	10%	25%	50%	75%	90%	100%
1	0	0	0	0	0	0.35	2.35
2A	0	0	0	0	0	0.35	2.35
2B	1.18	0.82	1.41	1.76	1.76	1.76	2.35
3	2.47	2.94	2.82	3.06	2.71	2.71	2.35
6	0	0	3	24	20	24	20

Vs	Amount of Class 2B DG						
	0%	10%	25%	50%	75%	90%	100%
1	0	0	0	0	0	0.1	1.18
2A	0	0	0	0	0	0	1.18
3	2.47	3.06	2.35	0.82	1.53	0.5	1.18
5	2.35	1.76	1.76	1.76	1.29	0.8	1.18
6	0	0	0	2.47	1.18	0.7	1.18

Vs	Amount of Class 6 DG						
	0%	10%	25%	50%	75%	90%	100%
1	0	0	0	0	0	0	0
2A	0	0	0	0	0	0	0
2B	1.18	0.71	1.18	2.35	0	0	0
3	2.47	2.94	2.71	2	0	0	0
5	2.35	2.71	2.35	2.59	0	0	0


30
25
20
15
10
5
0
Number of ROs > 2 s
0%
10%
25%
50%
75%
90%
100%
Fraction of Type 3 AI
1
2A
2B
5
6


140
120
100
80
60
40
20
0
Number of ROTs > 2 s
10%
25%
50%
75%
90%
Fraction of Type 3 inverters with RT
1
2A
2B
3
6

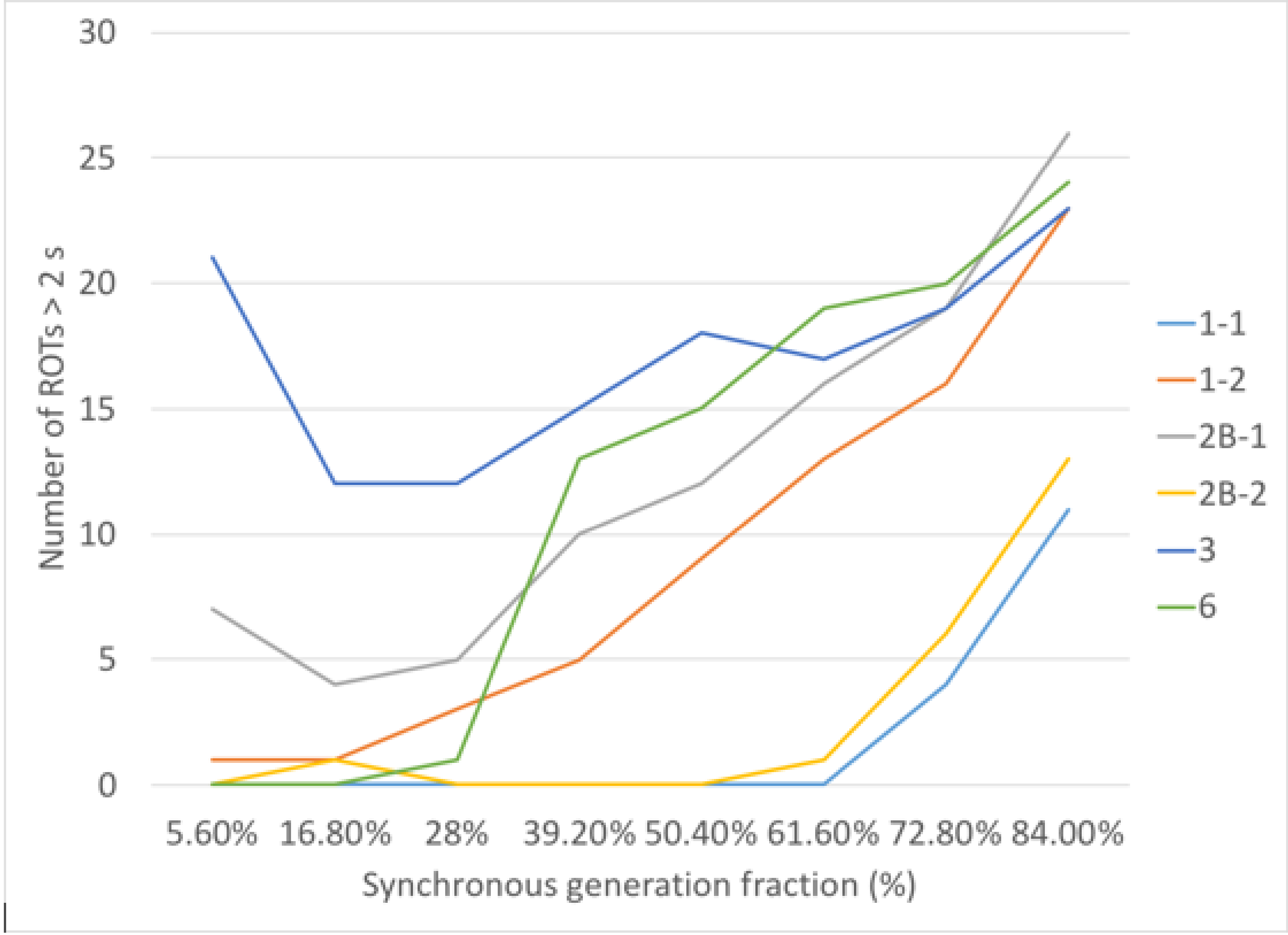


Figure 8. Number of loading scenarios in which ROTs exceeded 2 s for each inverter example tested, as a function of the fraction of synchronous generation within the island, without RTs.

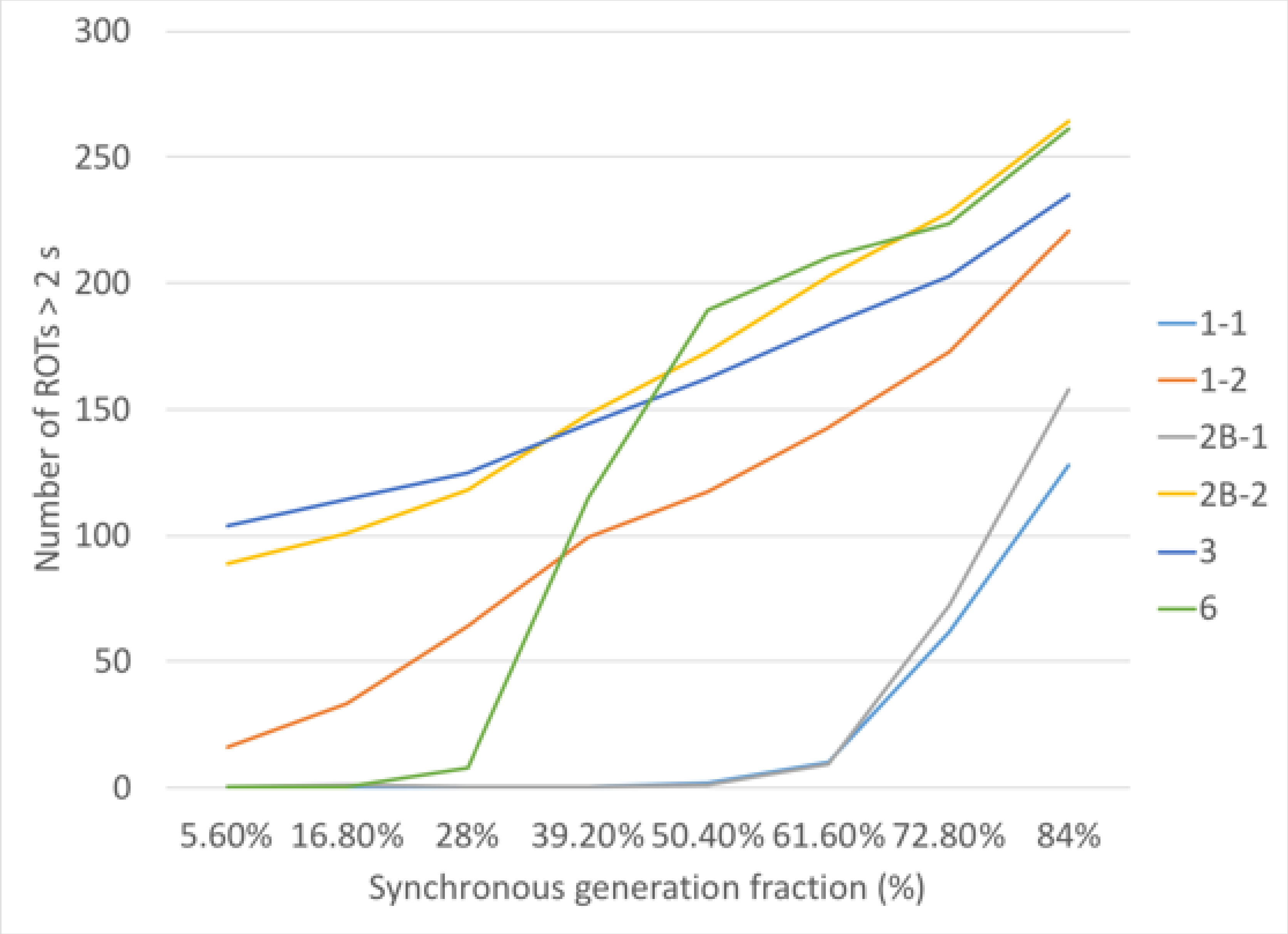


Figure 11. Number of loading scenarios in which ROTs exceeded 2 s for each inverter example tested, as a function of the fraction of synchronous generation within the island, with RTs.

Learning so far

- Some representatives of some classes perform significantly better than others in a general sense (SFS and quasi-SFS).
- We definitely DO see degradation when RTs are applied.
- The evidence regarding grid support functions like V/V, f/W etc. is mixed, but so far seems to be a negligible impact on AI overall.
- As a general rule, mixtures of methods do not perform as well as individual methods, but there are exceptions.
- AI becomes more difficult when sync gens are added, in most cases (but not all).

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Sensitivity study

Factors being considered

- Irradiance/inverter output power
- Distribution of the load along the circuit
- Distribution of DERs along the circuit
- Phase-phase load imbalance
- Circuit impedance between DERs or loads
- ZP-load Z and P fraction
- Motor load fraction
- Nonlinear load (harmonic current injection level)

AI methods included

- Type 1 (SFS—did best in earlier work)
- Type 3 (Z detection only—did worse in earlier work)
- RoCoF "on"
- Using manufacturer-specific models

Work completed so far (all with RoCoF)

- ✓Irradiance/inverter output power
- ✓Distribution of the load along the circuit
- ✓Distribution of DERs along the circuit
- Phase-phase load imbalance
- ✓Circuit impedance between DERs or loads
- ZP-load Z and P fraction
- ✓Motor load fraction
- Nonlinear load (harmonic current injection level)

Results so far

- The main result so far is that RoCoF has retained a very high degree of effectiveness, even when Cat II compliant.
- We hope to redo the simulations so far without RoCoF to get a better idea of the sensitivities.
- The main factor that has made a difference so far is the presence of motor load.

Questions?

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